THE MALASPINA GLACIER.

BY

RALPH S. TARR.

The Malaspina is the largest glacier on the American continent, and probably the largest in the world outside of the Frigid Zone. It lies on the seaward side of Mount St. Elias and other peaks of the St. Elias chain to the southeast of the main mountain. Altogether it has an area of approximately 1,500 square miles, which is more than the area of the State of Rhode Island.

After the purchase ofAlaska, a United States Coast Survey expedition visited this region and reported the presence of an extensive low-lying plateau between the sea and the base of the mountains. On a subsequent visit, later in the season, when the snow had melted from the lower levels, the true nature of this plateau was discovered by the eminent Alaskan explorer, Dr. Dall, who, for the first time announced the existence of a remarkable and extensive ice plateau, to which he gave the name Malaspina in honour of the Spanish explorer who visited this coast over a century ago.

One might wonder that even the snow-covered glacier could have been mistaken for low-lying land. The reason for this mistake was, however, made clear by the later explorations of the late Professor I. C. Russell. In 1890 he made an expedition having for its object the ascent of Mount St. Elias, in the course of which he crossed a part of the Malaspina Glacier, and looked down upon the greater portion of it. Being unsuccessful in his attempt to ascend the mountain, he returned in the following year, crossing the glacier in another part, and, on his retreat, skirting the seaward face for fully two-thirds of its length. Other explorers have crossed the Malaspina at different points, notably Prince Luigi, Duke of the Abruzzi, who, of all the explorers, alone succeeded in ascending Mount St. Elias.

It is from Professor Russell's descriptions that we have gained most of our knowledge of the remarkable ice plateau of the Malaspina Glacier; for he looked at it with the eye of a trained geologist and the keen interest of an expert glacialist. It was my fortune to see the Malaspina Glacier in 1905, when it still retained the characteristics described for it by Russell; and again I saw it in the summer of 1906, when its eastern portion had undergone such a remarkable change as to alter it completely from its former condition. Because of this

sudden and unexpected change in the character of the glacier, which, so far as I know, is unique and without parallel, I propose first of all to describe somewhat fully its condition prior to 1906, then point out what changes have occurred.

The St. Elias chain rises boldly to heights of from 10,000 to 18,000 feet. Almost the entire elevation is visible from the sea-level. The low-lying plateau of the Malaspina Glacier, which reaches a height of not over 2,000 feet, alone interrupts the view. It is one of the grandest mountain panoramas in the world, in whch one can see a sheer elevation of 16,000 feet in a single view.

The grandeur of the St. Elias mountain range is enhanced by the

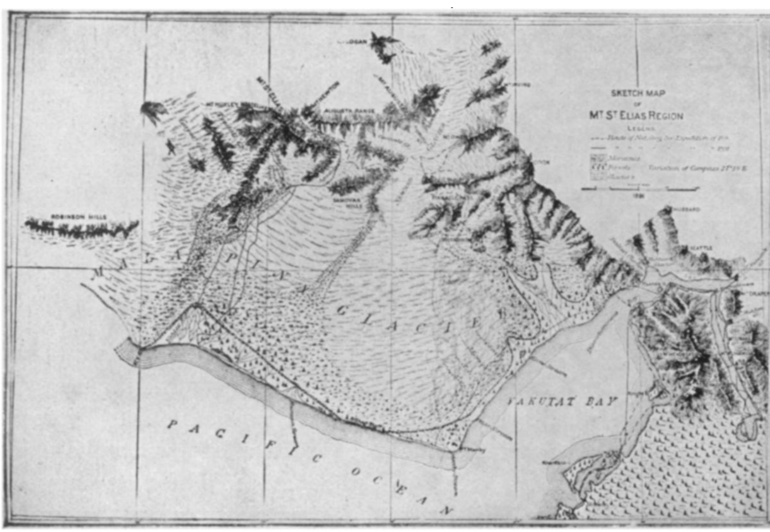

FIG. I—RUSSELL'S MAP OF MALASPINA GLACIER.

massive snow-cover which mantles the slopes, where not too steep, at all elevations above 3,000 feet. This mountain chain rises on a windward coast, and the winds, warmed and dampened in their passage across the warm waters of the North Pacific, are caused to precipitate much of their vapour content in ascending these great slopes. In consequence of these conditions, the rainfall of this part of the Alaskan coast is exceptionally heavy. At Nuchek, at the mouth of Controller Bay, just northwest of the Malaspina Glacier, the annual rainfall is 190 inches, making it one of the most rainy places in the world outside of the tropical zone.

On the mountains this precipitation occurs in the form of snow; and if it is even approximately as heavy there as at sea-level, the amount

of snow falling annually must be enormous, since one inch of rainfall is equal to about ten inches of snow. We have no rainfall records on the mountain slopes, so that it would not be correct to say that because there are sixteen feet of rain at Nuchek each year, one hundred and sixty feet of snow would fall upon the mountains. At the same time the statement is warranted that, in all probability, the annual snowfall on the seaward face of the St. Elias chain must be measured in scores of feet. Snow falls upon these slopes at all seasons of the year. Again and again, after the July and August storms, I have seen the mountain slopes freshly whitened with the heavy snow that had fallen during the period that the peaks were wrapped in the clouds.

The effect of this heavy snowfall has been to give rise to enormous glaciers. Every mountain valley has its glacier, and the accumulation of ice in the valleys is so great as to give the appearance of a vast sheet of snow and ice with mountain peaks rising out of it. No better description of this condition could be given than that presented by Professor Russell in his account of what lay before him as he looked out from the high slopes of Mount St. Elias, northward over the system of mountains which extend the Saint Elias chain in that direction. Of this view he says: "I expected to see a comparatively low, forested country, stretching far to the north, with lakes and rivers and perhaps some signs of human habitation; but I was entirely mistaken. What met my astonished gaze was a vast snow-covered region, limitless in expanse, through which hundreds and perhaps thousands of barren, angular mountain peaks projected. There was not a stream, not a lake, and not a vestige of vegetation of any kind in sight. A more desolate or more utterly lifeless land one never beheld. Vast, smooth, snow-surfaces, without crevasses stretched away to limitless distances, broken only by jagged and angular mountain peaks."

From these great fields of snow and ice, glaciers descend through the mountain valleys toward the sea. Several of the very largest unite on the seaward base of the Saint Elias mountains to form the great ice plateau of the Malaspina Glacier. Of these, the largest, named from east to west, are the Marvine, Seward, Agassiz and Guyot Glaciers, the latter coming from the western side of St. Elias, the others from the eastern side. In addition there are innumerable minor glaciers contributing to the supply of the great ice plateau. The contributing glaciers are all normal valley glaciers of the type well known in the Alps, but, in the case of the larger ones, many times greater than the largest Alpine glacier. Many of the tribu-

taries, far exceeding in size and grandeur the Aletsch, Mer de Glace, and Rhone Glaciers, bear no names, and, in comparison with their greater neighbours, call for no special mention.

After emerging from their mountain valleys, these glaciers flow out upon a low-lying, moderately-sloping foreland, the exact nature of which is not known, since it is hidden beneath the ice plateau. Over this ice spreads, each glacier expanding to several times the valley width, and, with its expansion, diminishing in velocity. The several tributaries coalesce, forming one complete glacier, which, lying as it does at the foot of the mountains, has been called a *piedmont glacier* (Fig. 1). This is the original type, and, so far as known, the best existing example of piedmont glaciers.

While the Malaspina ice plateau forms a united whole, and from one standpoint possesses individuality, each of its several parts is, nevertheless, dominated by the influence of the valley glacier which supplies its ice. The lines of flow and the surface moraines clearly indicate the areas dominated by the several large, contributing valley glaciers. Because of this influence of the tributaries, the Malaspina consists of three great lobes, the western dominated mainly by the Guyot, the central by the Agassiz, the eastern by the Seward and Marvine glaciers.

Two of these lobes reach the sea, the western terminating along a part of its margin in the ice-cliff of Icy Cape, from which icebergs are discharged into the open Pacific; the eastern barely reaching the ocean, and being bathed by the ocean waves, though without discharging icebergs. This part of the glacier margin, known as Sitkagi Bluffs, is a moraine-covered ice-cliff, with a narrow beach at its base, supplied with rock fragments from the down-sliding of the moraine fragments which veneer the ice.

We have no measurements which permit us to determine the rate of movement of any part of this glacier system. It is evident, however, that the valley glaciers are moving with rapidity, as glacier movement goes, and that the velocity diminishes rapidly toward the sea, in the piedmont expansion of the Malaspina proper, becoming practically stagnant in places around the periphery.

These conditions give rise to some unusual features not common to ordinary glaciers. The mountain valley tributaries are quite like valley glaciers in all respects. They have their snow field supply-ground; their névé area; their valley glacier portion; their lateral and medial moraines; and their areas of crevassing where descending unusual slopes. Outside of the mountains these conditions change entirely. The slow movement of the ice gives little cause

for crevassing, and consequently the surface is comparatively smooth, speaking now of its condition prior to 1906. It is, in fact, so free from areas of marked crevassing, that its surface has served as an

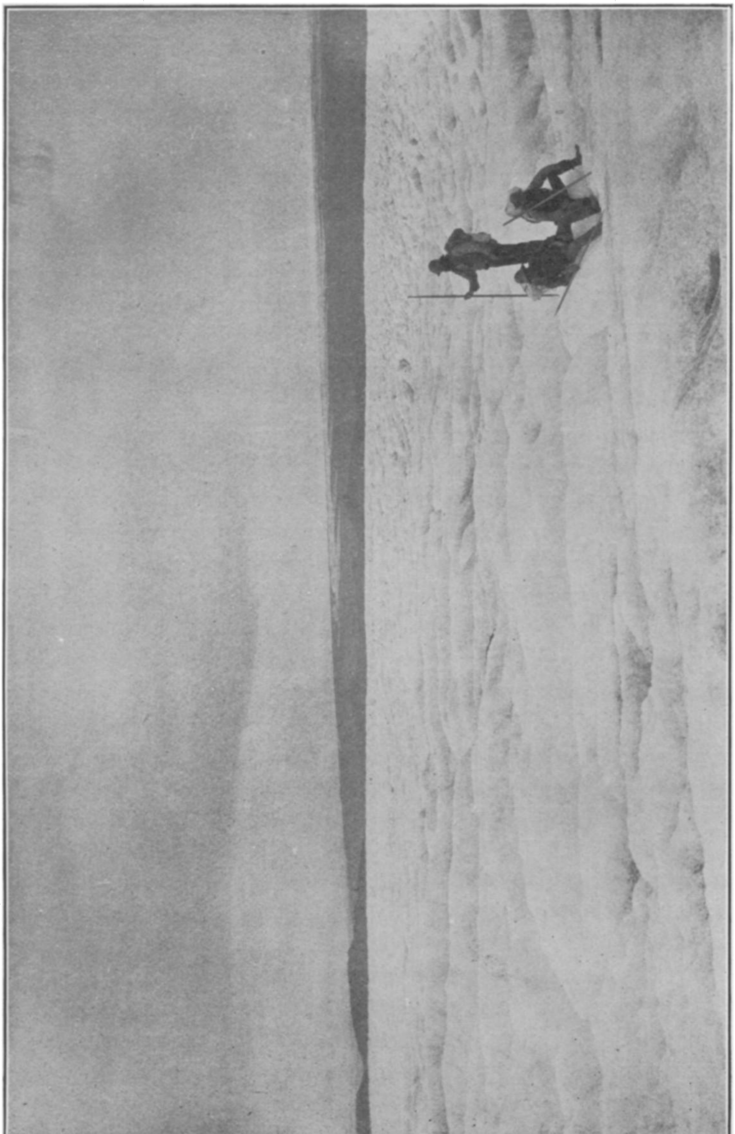

FIG. 2—SURFACE OF CENTRAL PORTION OF MALASPINA GLACIER. (PHOTOGRAPH, 1891, BY I. C. RUSSELL.)

excellent highway for carrying on sleds the outfit of the mountain-climbing parties which have crossed it (Fig. 2).

Since much of the surface of the Malaspina Glacier lies below the level of perpetual snow, it is subjected to great wastage under the influence of sun and rain during the summer season. On one of its tributaries, the Hayden Glacier, I found that the rate of lowering of the glacier surface during the latter part of July and early August amounted to four inches a day. This wastage is accomplished partly by evaporation, partly by the run-off of water which, after a short journey on the ice surface, finds its way into the ice, escaping at the margin through ice tunnels from which emerge violent torrents of great volume, heavily laden with sediment.

Scattered through the ice are numerous fragments of rock, some derived by abrasion along the glacier bottom and sides, but mostly supplied by the down-falling of rock from the mountain slopes, which tower above the valley portions of the glacier system. Some of these rock fragments are caught and borne away in the running waters supplied by the wasting glacier, but the great majority are left behind. The accumulation of these rock fragments causes a concentration at the surface which increases rapidly toward the glacier margin. They are residually concentrated by the wastage of many feet of ice which held them in more or less scattered condition. Thus the rock fragments disseminated through scores, or even hundreds, of feet of ice are assembled together on the glacier surface near its margin.

In consequence of these conditions, the periphery of the Malaspina Glacier is covered by an extensive desert waste of rock debris, over which one may walk with only occasional evidence of the presence of underlying ice (Fig. 3). This morainic blanket protects the ice from sun and rain and thus checks recession of the glacier margin. Where the moraine is thin the retardation of melting is only slight; where thick, the wastage is greatly decreased. Since the cover of moraine is not uniform in thickness, the melting of the underlying ice is irregular, so that the debris-field consists of alternate hummocks and kettles, due to irregular settling, as the ice melts beneath it. Over this morainic waste travel is slow and tedious, and sledding, of course, impossible. The surface is strewn with angular blocks of rock; the way lies up and down hill in whichever direction one may go; the footing is treacherous, for one may at any moment find himself upon slippery ice hidden by a mere film of moraine—or his foot may rest upon a block of rock which is just ready to tumble down the slopes of the morainic hummock.

In several parts of the periphery of the Malaspina Glacier, the movement of the ice is so nearly checked, and wastage is so com-

pletely interfered with by the thick blanket of debris, that the morainic soil is stable enough to permit the growth of vegetation. In some places it is only alder that finds a foothold; elsewhere forests

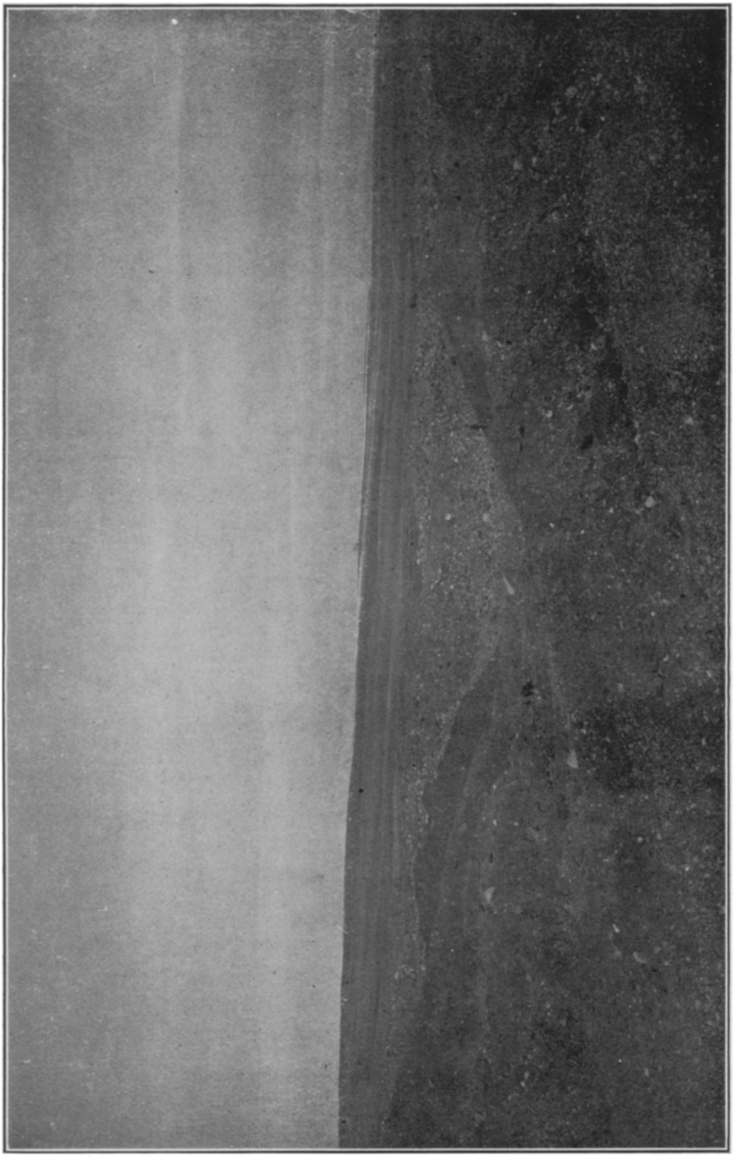

FIG. 3—MORAINE COVERED SURFACE OF MALASPINA GLACIER NEAR POINT MANBY. (PHOTOGRAPH, 1891, BY I. C. RUSSELL.)

of cottonwood have developed; and in some places the spruce forest of the Alaskan coast thrives upon the ice with apparently as much luxuriance as on the land itself (Fig. 4).

This condition of plant-covered ice margin is developed in other neighbouring glaciers; for example, the Lucia and Atrevida Glaciers. In these cases it is wholly impossible, in some portions, to tell exactly where the edge of the glacier actually lies.

In the summer of 1905, I made studies of the glaciers in and around Yakutat Bay, an inlet which pierces the outer portion of the Saint Elias range just southeast of the Malaspina Glacier. In the summer of 1906, I made another journey to this region, intending, if possible, to cross the Malaspina from east to west, following for the first part of the journey the route used by Professor Russell in 1890. The journey which was so easily accomplished by Professor Russell in 1890, and a part of which two members of my party traversed with no difficulty whatsoever in 1905, was in 1906 entirely impossible.

The Marvine Glacier, which supplies the ice of and therefore dominates the extreme eastern part of the Malaspina, including all that which comes down to the shores of Yakutat Bay, was transformed to a sea of crevasses from far up its mountain valley to its very end by the shores of the bay. Professor Russell crossed the Marvine Glacier in 1890 at the point where it comes out of its mountain valley, and he encountered no difficulties worthy of mention. In 1906 this part of the glacier was a labyrinth of crevasses from one side of its valley to the other, a distance of approximately four miles. The surface then bristled with jagged pinnacles, and the ice was cleft by a maze of yawning crevasses. From this point down to the sea, a distance of fifteen miles, the entire eastern portion of the Malaspina Glacier was broken into an impassable condition (Fig. 5). The area of crevassed ice expanded toward the sea until, along the shores of Yakutat Bay, the crevassed ice had a width of seven or eight miles. It was along this seaward margin that Professor Russell travelled on his retreat in 1891, passing over the waste of moraine described above. In 1906 the entire seaward periphery of this part of the glacier was so broken that it would be impossible for a party to travel across it. It was in this section, too, that the Duke of the Abruzzi entered upon the Malaspina Glacier on his way to Mount St. Elias. Where he so easily crossed, one could not now possibly enter upon the Malaspina Glacier without cutting ice steps for almost the entire distance.

The eastern margin of the Malaspina is skirted by a great glacial torrent known as the Kwik River, which flows over a broad alluvial fan that it is rapidly building up with sediment brought from the glacier. We travelled for seven miles up this valley along the very

margin of the broken glacier. Previously this ice margin had been covered by a blanket of morainic waste, and over a large part of the area had supported an alder thicket and cottonwood forest, in which

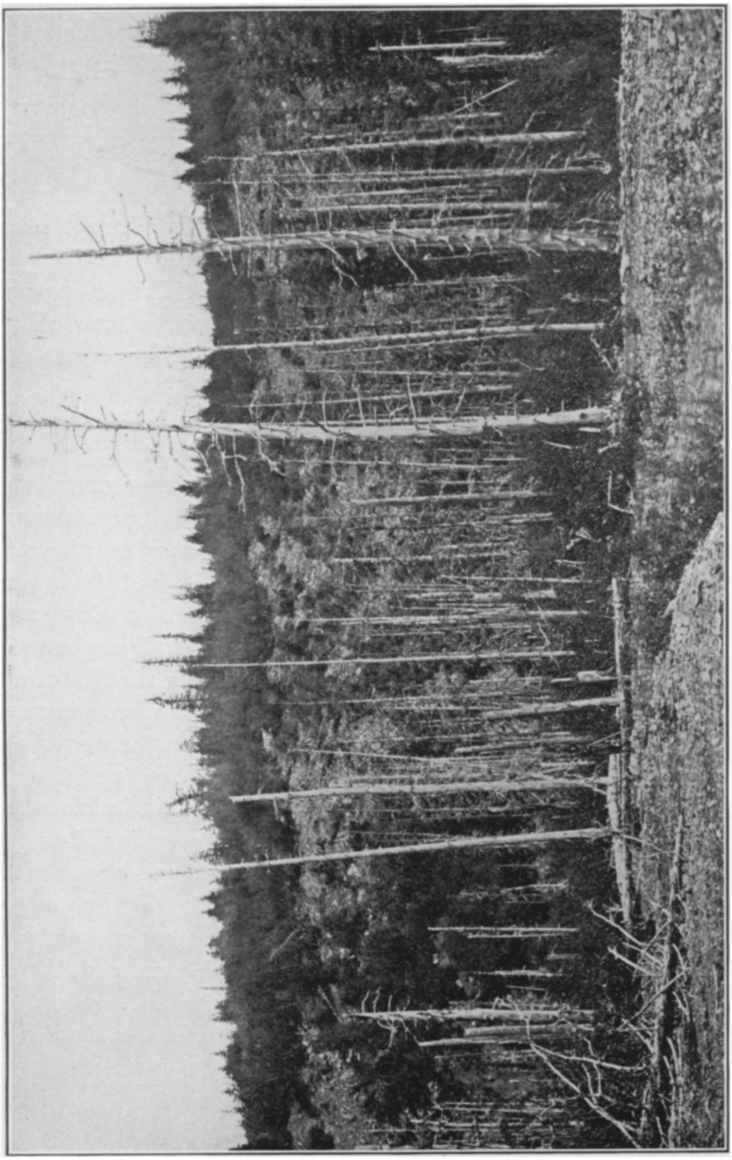

FIG. 4—SOUTHERN MARGIN OF MALASPINA GLACIER, SHOWING FOREST GROWING ON THE GLACIER. (PHOTOGRAPH, 1891, BY I. C. RUSSELL.)

some of the trees were at least 50 years old, indicating a period of stagnation of not less than half a century. The morainic soil had

attained a depth of from ten to fifteen feet, and on it vegetation grew freely. The forward movement of the glacier had broken the ice, pushing the blocks out from beneath the soil and transforming the glacier edge from a moderately sloping margin to a steep, jagged ice-cliff.

Into the crevasses and down the face of this cliff the soil was rapidly falling; and, as the trees were undermined by the removal of the soil from around their roots, they, too, went crashing into the crevasses and down the front of the ice. As we passed along the margin we heard and saw the falling of innumerable trees (Fig. 6). All the trees, whether fallen or standing, had fully developed their foliage, demonstrating conclusively that the changes by which they were being destroyed had occurred entirely within the growing season of 1906. The ice itself was cracking, grinding and falling as we passed along its margin, proving that the advance was even then in progress.

Long blanketed by its soil-cover, the ice platform had been almost completely protected from melting. Now, however, the great rents had opened it to the air and it was melting with great rapidity. The soil, washing down over the broken ice blocks, so discoloured them as to give them the appearance of rock; and in many places the steep, broken ice-cliff, with trees growing upon it, had the appearance of a frost-riven precipice in the mountains of New England or the Adirondacks. By this rapid melting, water was being supplied in great quantities; new streams had developed; and, heavily burdened with sediment supplied by the downsliding morainic soil, the streams were building extensive alluvial fans that were encroaching upon and destroying the forest which grew at the margin of the glacier. It was a marvellous change, almost weird in its character, to see a glacier, after at least a half century of stagnation, thus suddenly spring into activity, and carry with it the destruction of the ice, the soil and the forest-cover.

Of the many other glaciers in the Yakutat Bay region, three had undergone similar change, and two of these, in the summer of 1905, we had walked over freely and without encountering crevassing. In 1906 they were utterly impassable. Two or three others show signs of the coming of an advance by crevassing high up the mountain valley. In the remainder no signs of coming change were observed.

So far as I know, no similar change in glaciers has ever been observed. It is not uncommon for the terminus of valley glaciers to slowly advance or recede, and sometimes to change from recession to advance. But for a glacier within a period of ten months to abso-

lutely change its character, from a smooth surface, easily traversed, to a labyrinth of crevasses, rendering the entire glacier impassable, has been, I believe, hitherto unknown.

FIG. 5—CREVASSED EASTERN PORTION OF MALASPINA GLACIER, 1906. (PHOTOGRAPH BY C. VON ENGELN.)

In seeking an explanation of this remarkable phenomenon, one cannot appeal to ordinary causes. After a careful consideration of

all hypotheses which could be thought of, I have been forced to abandon all but one, which alone seems capable of explaining all the phenomena, and against which no facts could be marshalled.

In September, 1899, this region was visited by a series of earthquakes two of which attained such exceptional intensity as to warrant their classification as world-shaking. They were recorded on seismographs at points as remote as Tokio in Japan, Cape Town. South Africa, and Rome, in Italy. A recent publication by an eminent seismologist has selected these earthquakes as among the most violent recorded on the seismographs of the world. My own observations along the shores of Yakutat Bay prove that during the earthquakes the land was uplifted from 10 to 47 feet, this proof consisting of the evidence of elevated beaches on which marine animals, notably barnacles, were still clinging. The evidence of prospectors is conclusive that during the shocks enormous masses of snow, ice and rock were shaken down from the mountain slopes.

If a slight increase in snowfall occurs in the supply ground of a valley glacier, it starts a wave which, passing from the reservoir, extends down the glacier, ultimately reaching the end and causing it to slowly advance. What, then, must have been the result of the sudden addition of enormous quantities of snow and ice to the névé region of the glaciers in the Saint Elias mountains? No other answer could be given to this question than that a correspondingly great wave must have resulted from such unusual increase in supply.

Exactly what would follow from the passage of such a wave down the glacier cannot be told from previous experience; but, on general principles, it seems highly probable that its effect would be to cause a sudden forward movement, accompanied, no doubt, by pronounced crevassing. From the evidence of actual conditions in the glaciers of this region, it seems clear that such a result has actually followed from the cause which we know to have occurred. The chief difficulty lies in the fact that the effect has followed so quickly upon the cause, and that it has produced such sudden and startling results.

That the phenomenon has not been previously observed, is, in reality, not so very remarkable, for it could occur only in a region where three exceptional conditions occur: (1) Well-defined glaciers, (2) immense snow fields, (3) violent earthquakes. All three of these conditions are present in the Saint Elias region. Doubtless they occur also in other mountains, as, for example, the Himalayas; but the final cause for such an advance--namely, earth-shaking, occurs at widely-separated intervals, and the sections most likely to be

affected are, like this very region of the Saint Elias mountains, remote from centres of population, and consequently not likely to be observed closely. It is, therefore, not at all impossible that similar changes have occurred in other glacial regions, having hitherto escaped attention.

What the future has in store for the glaciers of the Saint Elias mountains as a result of the cause that has forced some of them forward, is not certain; but it would be surprising if some of the other glaciers of the region do not also advance in the near future. It is, in fact, not at all unlikely that all the large glaciers contributing to form the Malaspina will feel the impetus of the thrust which so far has pushed only the Marvine forward. In that case the entire Malaspina Glacier will be transformed to the condition now noticed in its eastern portion. It will be interesting and important to watch these glaciers for the next few years; and it is to be hoped that means may be provided for doing this.

RACIAL AND REGIONAL STUDY OF THE VIRGINIA POPULATION.

BY

G. T. SURFACE.

The distribution of population in a new or old country affords an essential key for determining the factors of geographic control and economic response. In this brief discussion we cannot hope to do more than point out some of the salient facts relative to the establishment, evolution, and distribution of the people of Virginia.

The Indians, who were in possession of the territory prior to colonization, divided themselves into three confederacies—the *Powhatans, Mannahoacs,* and *Monacans.* The Powhatan confederacy occupied the Coastal Plain region and southern Piedmont, and consisted of 30 tribes; the tribes inhabiting the headwaters of the Potomac and the Rappahannock Rivers were attached to the Mannahoacs; while those of the headwaters of the James River and the Great Valley belonged to the powerful Monacans. The territory of the Monacans was always referred to by the eastern tribes as "the stony region." From this we see that the aboriginal people were distributed and divided according to distinct economic and physiographic conditions. The tribes of the three confederacies spoke languages so radically